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Three new species of precious coral (Anthozoa: Gorgonacea, genus *Corallium*) from Pacific waters

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Abstract.—Two new species of *Corallium* from New Caledonia with the consolidated axial skeleton having smooth pits with beaded margins accommodating the autozooids are described, *Corallium thrinax* with double-club sclerites, *C. nix* without. A third new species, *C. kishinouyei,* lacking smooth, well-defined axial pits and lacking double-club sclerites, is described from Cross Sea Mount south of Hawaii. Preliminary observations of axis formation are reported.

Program BIOCAL conducted in 1985 by ORSTOM aboard R/V *Jean Charcot* in the vicinity of New Caledonia obtained two species of the genus *Corallium* that cannot be assigned to any species heretofore described. Investigations of seamounts south of the Hawaiian Islands in 1993 by the Woods Hole Oceanographic Institution using the research submersible *Pisces V* obtained another undescribed species. These are now placed on record.

Suborder Scleraxonia Studer, 1887
Family Coralliidae Lamouroux, 1812
Genus *Corallium* Cuvier, 1798

Synonymy.—See Bayer, 1956:70; 1964: 466.

Type species.—*Madrepora rubra* Linnaeus, by subsequent monotypy, Lamarck, 1801.

Diagnosis.—Dimorphic Gorgonacea with continuous, solid, calcareous supporting axis without hollow core. Coenenchymal sclerites including 6-, 7-, and 8-radiate capstans sometimes asymmetrically modified as "opera-glass forms" or "double clubs," spindles, rods, and crosses.

Remarks.—Following the conclusion by Lacaze-Duthiers (1864) that the calcareous skeleton of *Corallium rubrum* is composed of sclerites cemented inseparably to form a continuous, unsegmented axis, the genus *Corallium* has been classified in the suborder Scleraxonia, in which the supporting axis unquestionably is composed of more or less completely fused sclerites as is the case in such families as the Paragorgiidae, Briareidae, and Melithaeidae. However, thin sections of the axis of *Corallium* examined under the light microscope do not show convincing evidence of spicular structure in spite of the statements to the contrary by various authors up to the present time (Müller 1910, Kükenthal 1924, Hyman 1940, Bayer 1956, Weinberg 1976).

It has now been demonstrated that in *Corallium rubrum* formation of the axis at the apex of branches begins as an agglutination of sclerites that become immersed in "rectilinear" calcite, which later comprises the predominant structural component (Grillo et al. 1993). This finding supports the inclusion of *Corallium* (family Coralliidae) in the gorgonacean suborder Scleraxonia.

However, Lawniczak (1987) concluded that in *C. johnsoni* Gray the axis is composed entirely of fibrocrystalline calcium carbonate, without inclusion of sclerites. As it is illogical to assign species otherwise closely similar in morphological (dimorphic

polyps) and skeletal (sclerites of virtually identical size and form) characters to different orders (and, necessarily, different families) on the basis of a percieved difference in skeleton formation observed in a limited sample of a rare and poorly known species, the family Coralliidae is retained in the Scleraxonia pending a wider investigation of axis formation in as many species of *Corallium* as can be obtained for study.

The description of *Corallium thrinax,* new species, was originally composed in French by Jeffrey Stefani, translated into English and edited by F. M. Bayer, so the species correctly bears joint authorship. The descriptions of *C. nix* and *C. kishinouyei* were prepared solely by the present author.

Corallium thrinax Bayer & Stefani, new species
Figs. 1–6

Material examined.—New Caledonia, 23°06.50′S, 167°53.74′E, BIOCAL 1985, R/V *Jean Charcot* station DW-50, 240 m, 31-VIII-85. Sixteen colonies with holdfast, and some fragments: Holotype and 16 paratypes (NMNH Paris); 8 paratypes, USNM 96511 (SEM 1328–1331, 2416, 2466).

Diagnosis.—*Corallium* branched dichotomously and laterally with tendency to remain in one plane, small, usually with no more than three or four bifurcations and a few short lateral twigs; autozooids forming low verrucae concentrated on one side of the branches; axis with distinct pits bordered by prominent beaded rim located beneath autozooids. Predominant sclerites are 6-radiate capstans and double clubs ("opera glasses") with smooth, globose heads. Colonies white, sclerites colorless.

Description.—The colonies are small, sparingly branched dichotomously, often with a few short lateral twigs (Fig. 1). They range from 3.7 to 6 cm in height, and between 3 and 6 cm in width. The holdfast is a narrow basal expansion of the trunk. For the most part branching is in one plane, but in some colonies a branch may stand at nearly 90° from the plane of the principal fan. There are no anastomoses. In most cases there is a short main trunk, oval in cross section, about 0.6 cm × 1.2 cm in diameter, which bifuractes to produce principal branches approximately round in section, which in turn bifurcate as many as two or three times; a few short, blunt lateral twigs sometimes arise from one or more of the internodes between bifurcations. In some cases, principal branches 2–4 mm in diameter arise directly from the holdfast.

The surface of the axis is longitudinally grooved (Fig. 2) and covered with minute tubercles ornamented with thorny projections (Fig. 3 bottom). At the position of each autozooid, the axis has a distinct rounded pit 0.75 mm wide and 1.05 mm long (Fig. 3 top) bordered by a beaded rim that in some cases is interrupted by a narrow gap for passage of a coelenteric canal (Fig. 2 bottom).

Examination of the apex of the axis of a twig tip by SEM shows tubercles some resembling axial processes, others resembling the tubercles of sclerites (Fig. 4). Clearly recognizable sclerites partially embedded in axial calcite were not found on the single sample examined. This might be expected if that twig tip had ceased upward growth at time of collection. Owing to the destructive nature of such preparations, no further samples have been made for the present purposes of taxonomic description.

Autozooids form low, inconspicuous verrucae distributed predominantly on one face (the "front") of the colony, with only an occasional stray on the back surface (Fig. 1). They are indistinct unless artificially stained with crystal violet. The tentacles are retracted flush with the coenenchyme, their bases forming an 8-lobed margin of the verrucal orifice. The autozooids are seated in distinct, rounded axial pits with a beaded rim (Figs. 2, 3). Siphonozooids are scarce and distributed randomly in the coenenchyme, so inconspicuous that they can be distinguished only by staining with crystal violet.

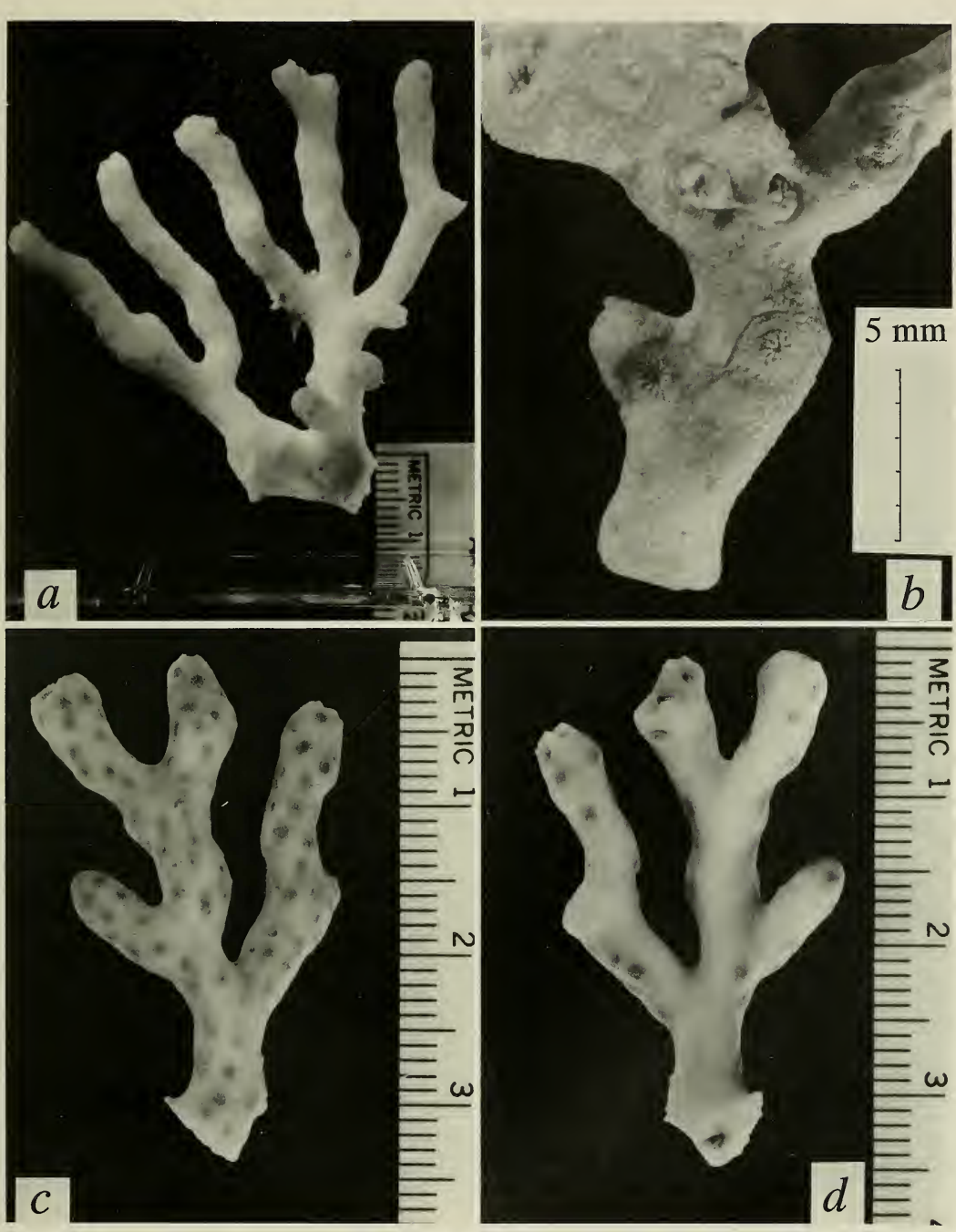

Fig. 1. *Corallium thrinax,* new species. a, Holotype colony; b, part of colony with zoanthid symbionts; c, Colony with autozooids stained with crystal violet, front surface; d, Colony with autozooids stained with crystal violet, back surface; paratype colony USNM 96511.

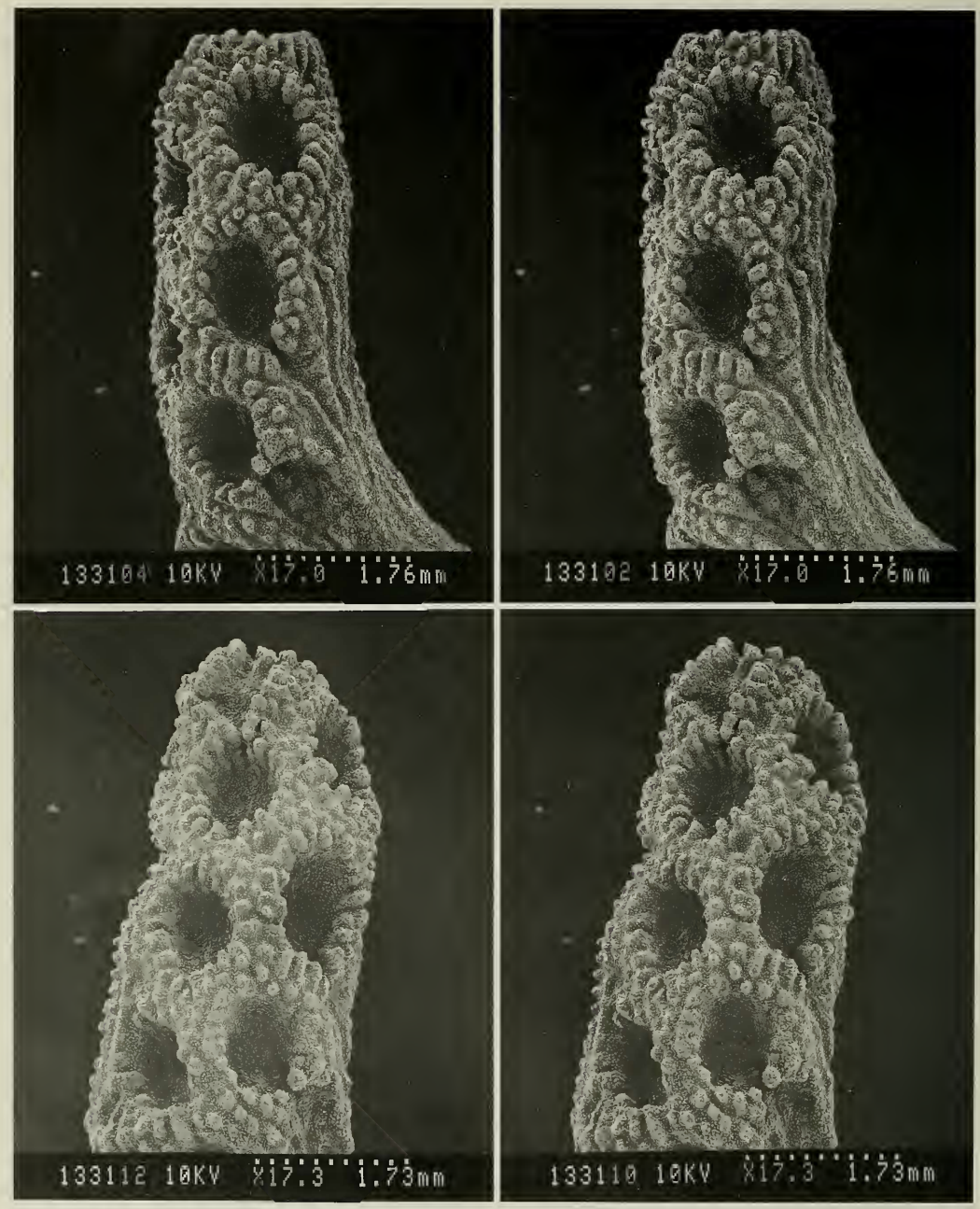

Fig. 2. *Corallium thrinax,* new species. Apex of axis in front and lateral views SEM 1331, stereo pairs.

The coenenchyme is so thin that the axial sculpture is exposed in areas subject to abrasion (Fig. 6 top). The longitudinal axial striations are clearly indicated through the coenenchyme, most clearly toward branch tips where the autozooids are closer together.

Sclerites (Fig. 5) of the coenenchyme include numerous 6-radiates up to 0.04 mm in length, many of which are modified as

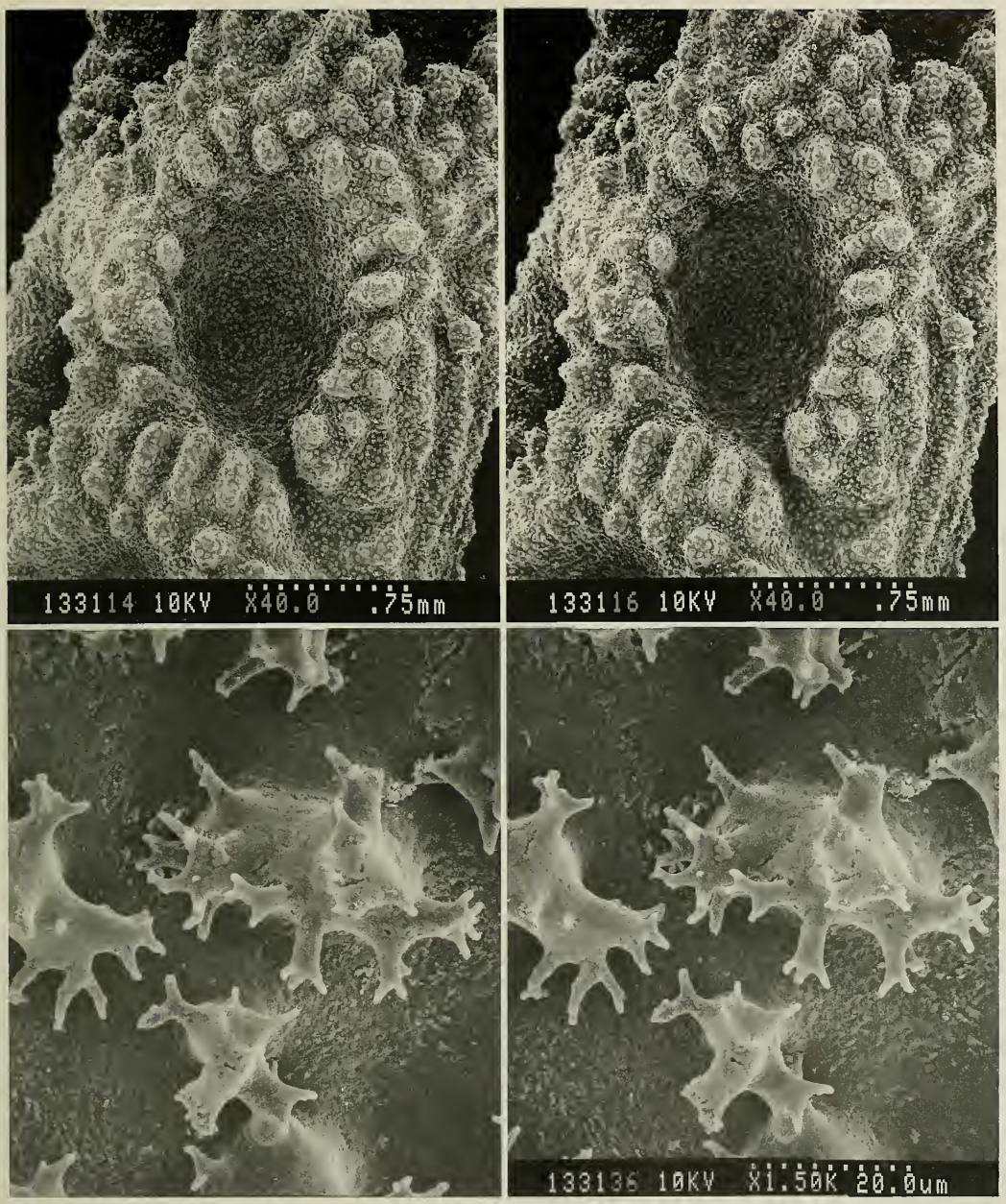

Fig. 3. *Corallium thrinax,* new species. Top, Axial pit at location of autozooid; Bottom, Axial protuberances. SEM 1331, stereo pairs.

globose double clubs by asymmetrical hypertrophy of two of the rays to form a pair of smooth, spheroidal processes. At the surface of the coenenchyme these lie crowded, with the spheroidal processes directed outward (Fig. 6 bottom). Sclerites intermediate between double clubs and 6-radiates with the hypertrophied rays more or less strongly modified are not uncommon. Irregular forms occur but are extremely rare. No crosses or 8-radiates were observed, and only a single small 7-radiate was found in

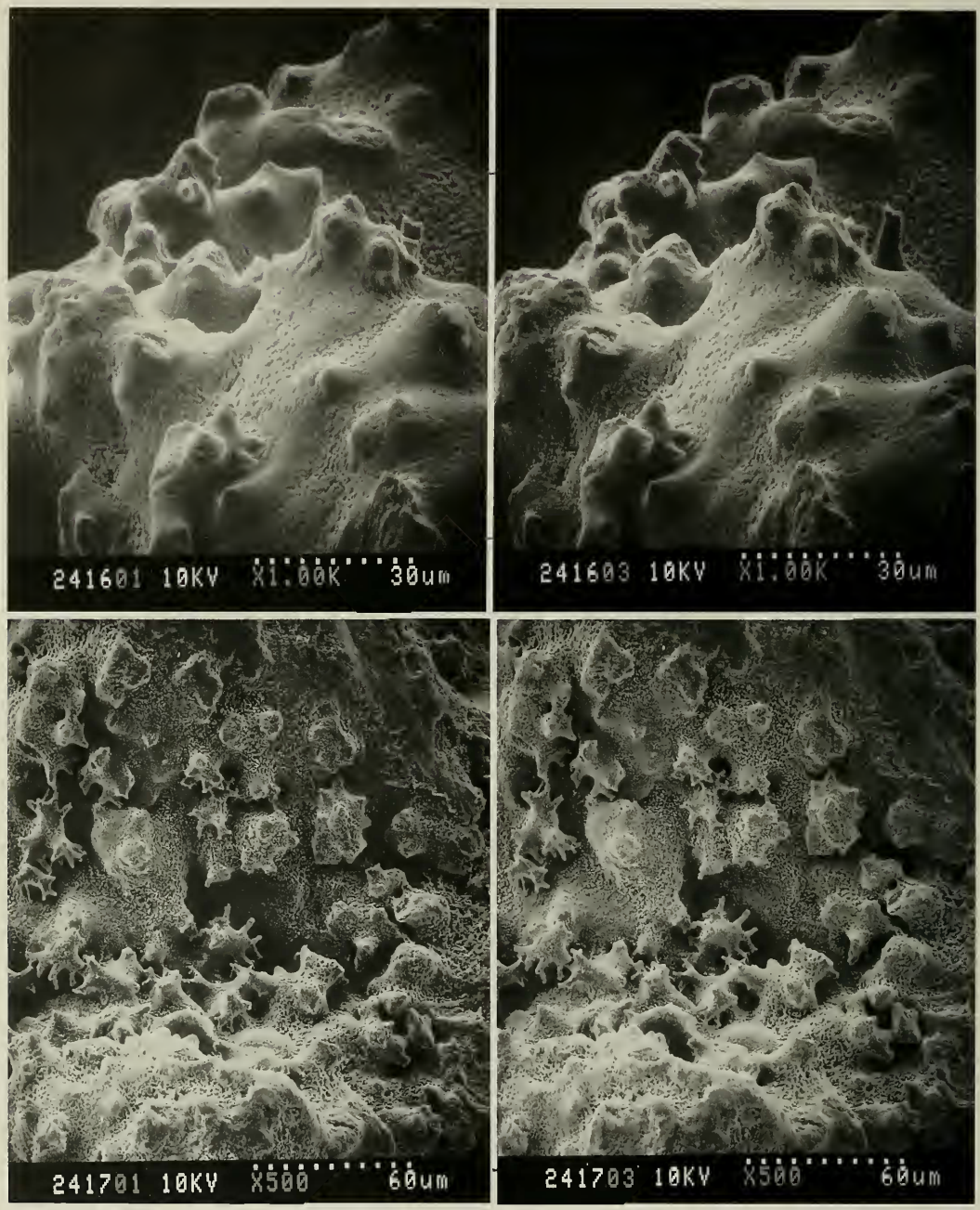

Fig. 4. *Corallium thrinax,* new species. Top, Apex of axis showing axial protuberances and tubercles similar to those of sclerites. SEM 2416, stereo pair; Bottom, Surface of axis near apex showing axial protuberances and tubercles similar to those of sclerites. SEM 2417, stereo pair.

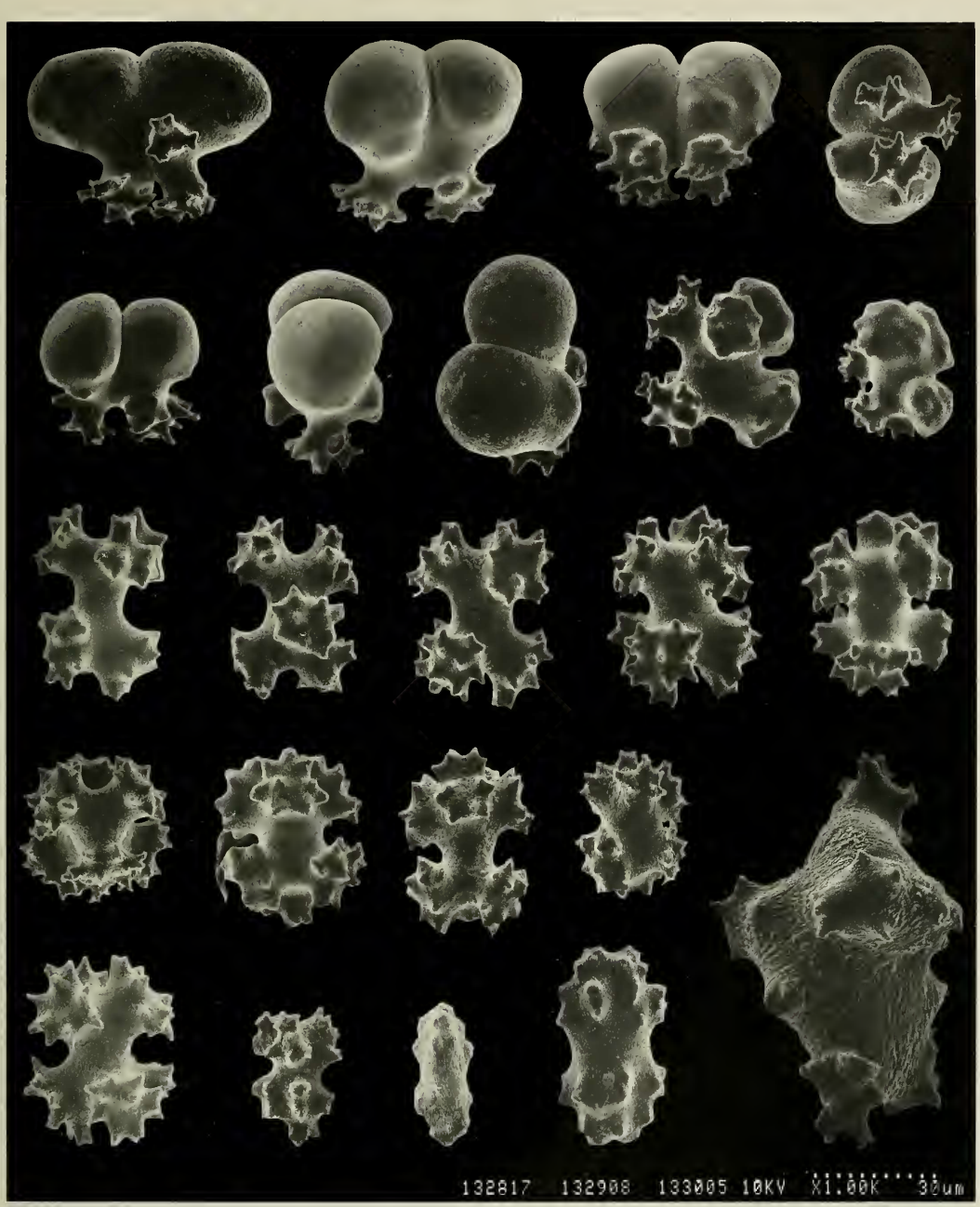

Fig. 5. *Corallium thrinax,* new species. Sclerites. SEM 1328–1330.

3 preparations for SEM. Small rods and 6-radiates are present in the tentacles, the distal ones decreasing in size to about 0.03 mm.

Colonies preserved in ethanol are white; the axis is white and the sclerites are colorless.

Comparisons.—The colonial form of *Corallium thrinax* is immediately distinguished from that of any other species of

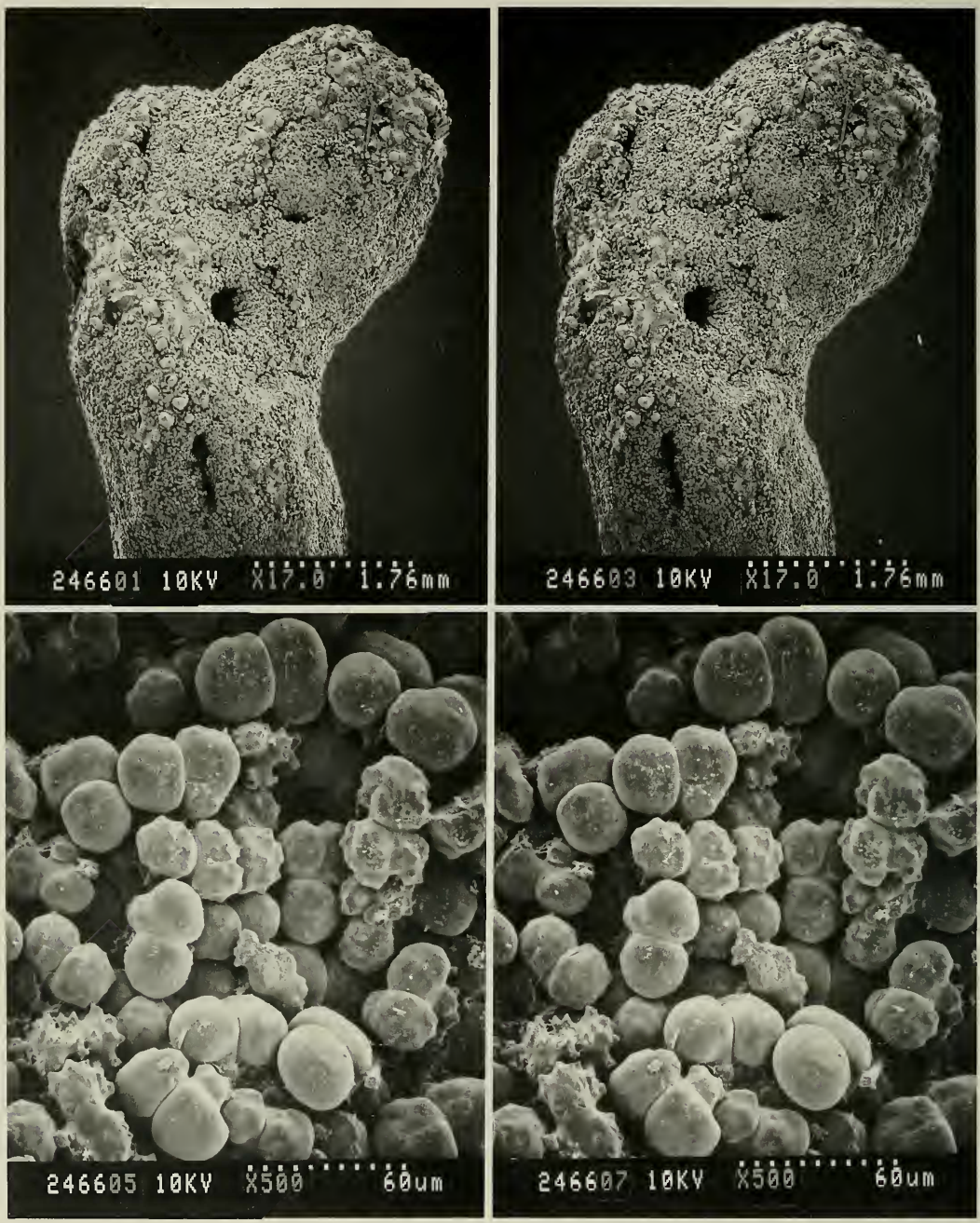

Fig. 6. *Corallium thrinax,* new species. Top, Tip of terminal twig; Bottom, Surface of coenenchyme showing predominance of double-club forms. SEM 2466, stero pairs.

Corallium known heretofore. Other nominal species having autozooids seated in axial pits with beaded rims are: *C. stylasteroides* Ridley, 1882, from Mauritius; *C. salomonense* Thomson & Mackinnon, 1910, from Salomon in the Indian Ocean; and *C. tortuosum* Bayer, 1956, from Hawaii, which was reduced, perhaps prematurely, to a sub-

species of *salomonense* (Bayer, 1993); *C. inutile* Kishinouye, 1903, from Japan; and *C. nix* new species, described herein.

The axis of *Corallium japonicum* Kishinouye also is marked by small pits beneath the autozooids (Kishinouye 1905:22), as is that of *C. elatius* Ridley (Kishinouye, 1905: 24) and *C. rubrum* (Linnaeus) (Grillo, Goldberg & Allemand, 1993:121, fig. 1c), but in those species (and probably others as well) the pits are not bordered by a distinct, beaded margin. Among those with beaded pits, *C. stylasteroides, C. salomonense* and *C. tortuosum* lack double clubs among the sclerites. *C. inutile* has double clubs of somewhat different outline and only 6-radiates but no 7- and 8-radiates, and differs further in its colonial form, pale pink axis and reddish cortex. *C. borneense,* which is salmon pink with red calices and quite differently branched, has double clubs of similar size and shape, but its autozooids form distinctly hemispherical verrucae and are not seated in rimmed pits in the axial skeleton.

Etymology.—*thrinax* from Greek θριναξ, a three-pronged fork, in allusion to the forked braching of the colonies. Noun in apposition.

Symbionts.—A few of the specimens are host to a balanoid barnacle that is partially overgrown by coral skeleton, and the branch tips of a few are overgrown with what appears to be a fasciculate hydroid. Near the base of some colonies there are symbiotic zoanthideans (Fig. 1b), but these are not invariably present as seems to be the case in both *C inutile* and *C. tortuosum.*

Corallium nix, new species
Figs. 7–10

Material examined.—New Caledonia, 23°06.50′S, 167°53.74′E, BIOCAL 1985, R/V *Jean Charcot* station DW-50, 240 m, 31-VIII-85. One branch apparently part of a larger colony, holotype, Muséum National d'Histoire Naturelle, Paris.

Diagnosis.—*Corallium* irregularly branched; autozooids on all sides of the branches, seated in distinct pits in the axis, bordered by prominent beaded rim. Predominant sclerites are short 8-radiate capstans and 6- and 7-radiates some of which are weakly asymmetrical but in the form of double clubs; crosses extremely rare. Colonies white, sclerites colorless.

Description.—As the only specimen appears to be no more than a branch of a larger colony, it is not possible to provide a description of the general aspect of the complete colony. The single branch (Fig. 7) is sinuously curved, thick, approximately round in cross section, and 6.2 mm in greatest diameter at the base. Its shape suggests that branching probably proceeds roughly in one plane, as often is the case in species of *Corallium.* It produces short terminal branchlets mostly from two sides in roughly the plane of curvature, but a few small ones arise from the "front" of the branch.

The surface of the axis is longitudinally grooved (Fig. 8), as usual covered with minute axial protuberances ornamented with thorny projections (Fig. 9). The axis has a distinct rounded pit 0.75 mm wide and 1.05 mm long at the position of each autozooid, bordered by a beaded rim that commonly is interrupted where a coelenteric canal passes through to connect with the gastrovascular cavity of the autozooid (Fig. 8). Owing to the limitations of material available for study, an intact terminal twig was not prepared for examination by SEM to avoid damage to the unique type specimen. As expected, no clearly recognizable sclerites partially embedded in the subapical rectilinear calcite were observed.

Autozooids are distributed on all sides of the branch and terminal branchlets (Fig. 10). They retract flush within the rim of the axial pits, the bases of the infolded tentacles forming an 8-lobed margin of the closed verrucal apertures. Their distribution is most clearly revealed by staining with crystal violet, which stains the structures within the gastric cavities more darkly than the surrounding coenenchyme so that they con-

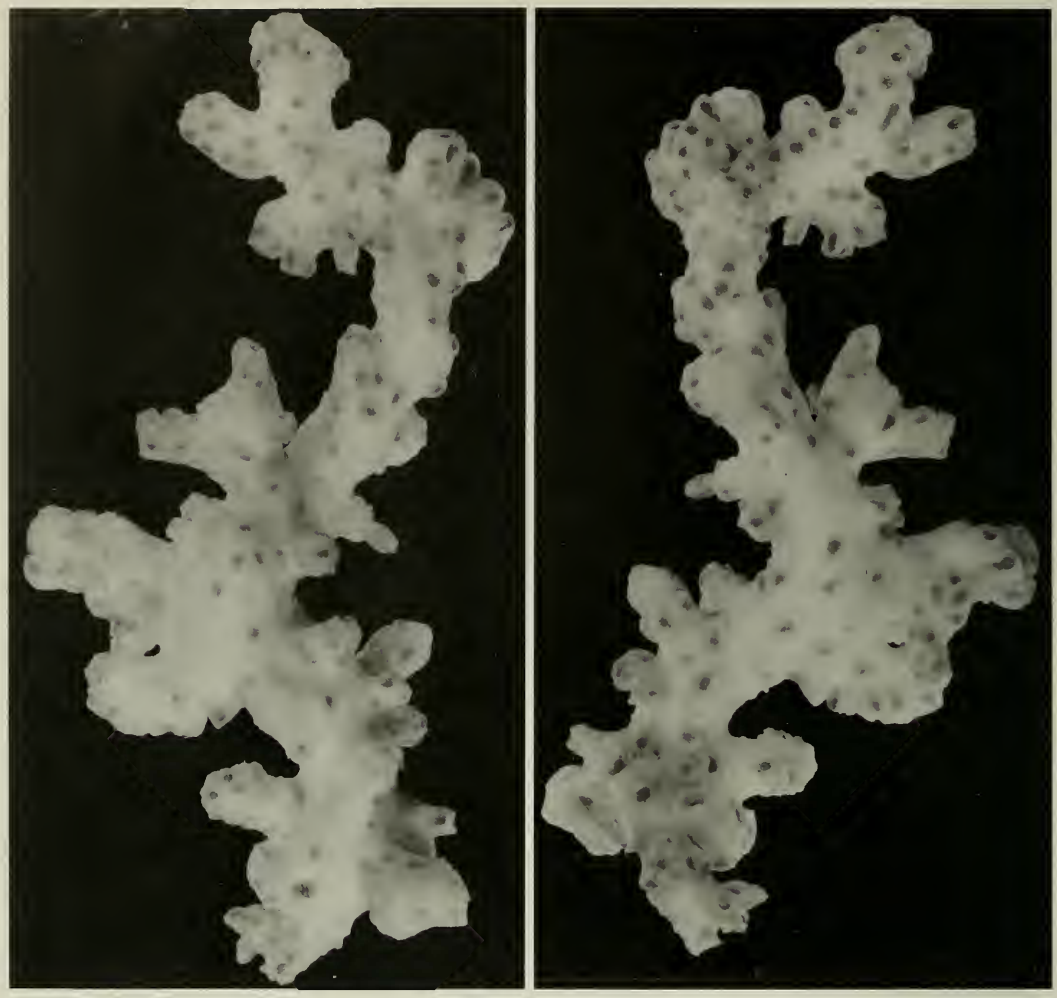

Fig. 7. *Corallium nix,* new species. Holotype branch with autozooids stained with crystal violet showing general distribution on front and back surfaces. Height overall, 5.75 cm.

trast sharply with the paler cortex as the highly soluble stain dissipates (Fig. 7).

The siphonozooids do not form distinct small verrucae and therefore are very difficult to detect, but commonly one is located in the tapered groove extending from the autozooid, and scattered individuals can be seen in the coenenchyme between and around the autozooids.

The coenenchyme is very thin, generally smooth but inconspicuously papillate in areas protected from abrasion, suggesting that elsewhere the minute papillae may either have been rubbed off during collection, or have contracted completely as the result of contact with other objects in the trawl. Inconspicuous sinuous longitudinal grooves indicate the location of the principal coenenchymal canals.

The predominant sclerites (Fig. 10) are short 8-radiate capstans reaching lengths of 0.06–0.07 mm, none of which are elongated as belted spindles, and very short, wide 6- and 7-radiates 0.04–0.06 mm long, which may be weakly asymmetrical but not clearly modified as double clubs ("opera glasses"); the shortest approach the tuberculate spheroid form. Crosses are absent or so

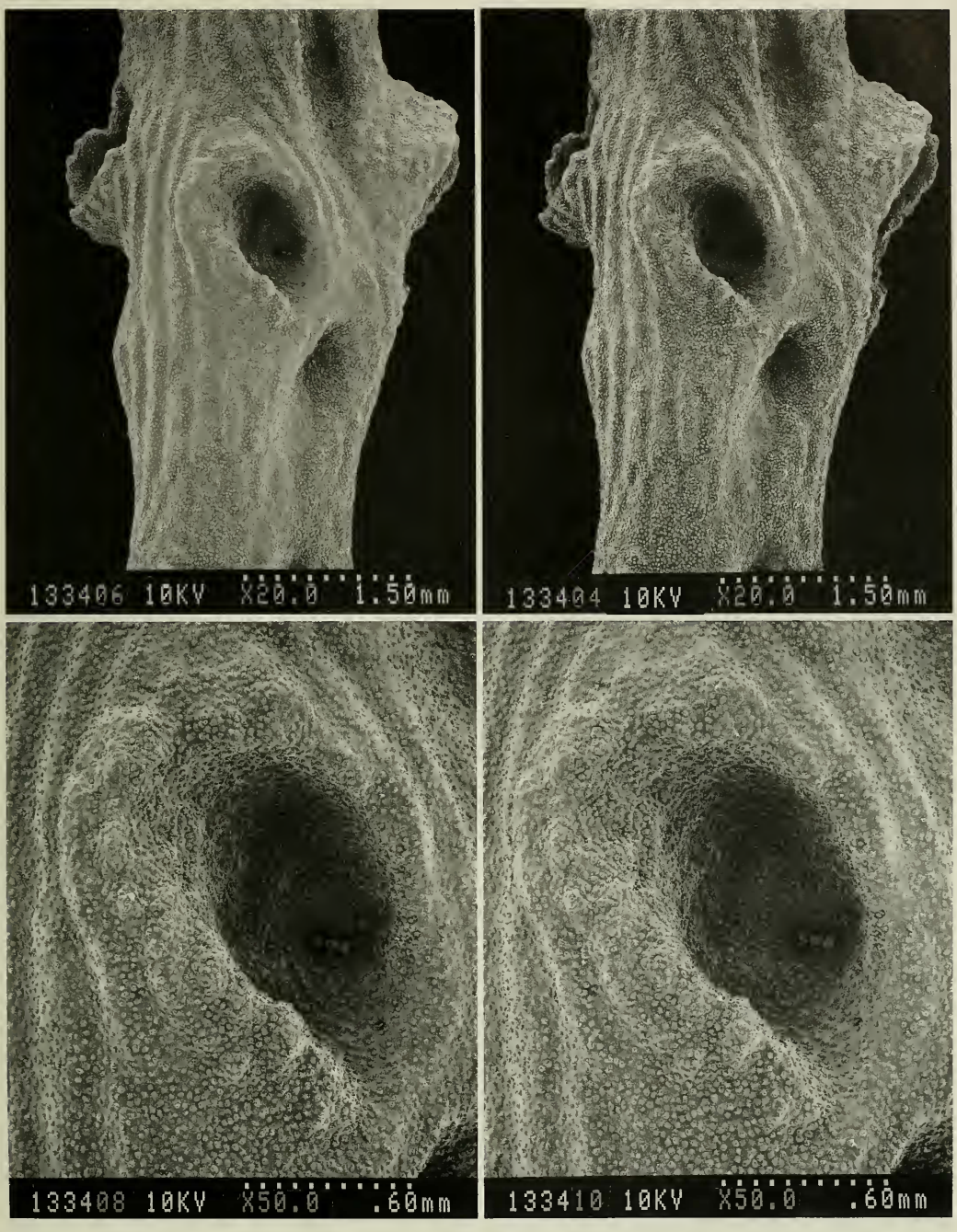

Fig. 8. *Corallium nix,* new species. Top, Part of branch with autozooid pits; Bottom, Detail of autozooid pit. SEM 1334, stereo pairs.

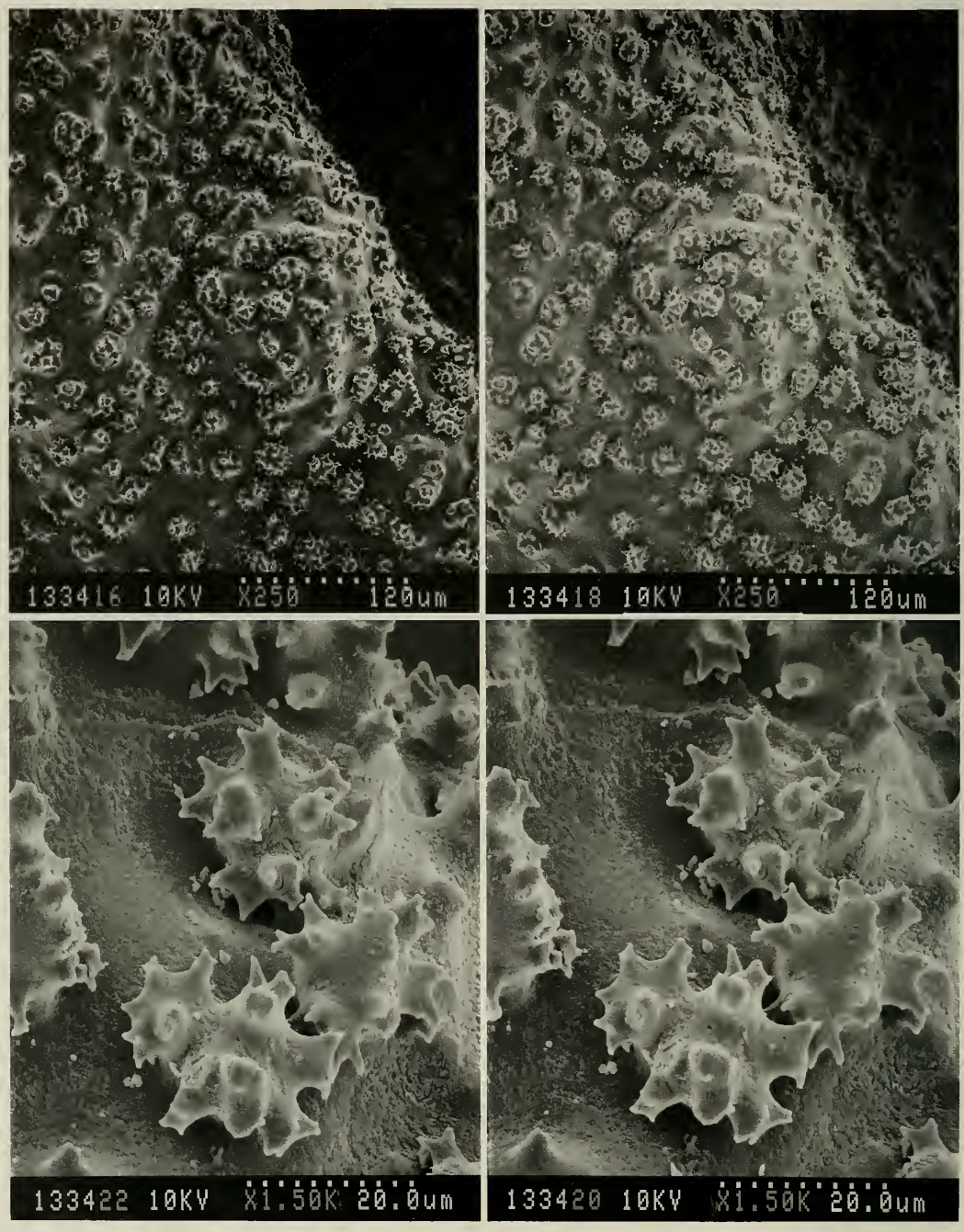

Fig. 9. *Corallium nix,* new species. Top, Surface of axis with axial protuberances; Bottom, Detail of axial protuberances. SEM 1334, stereo pairs.

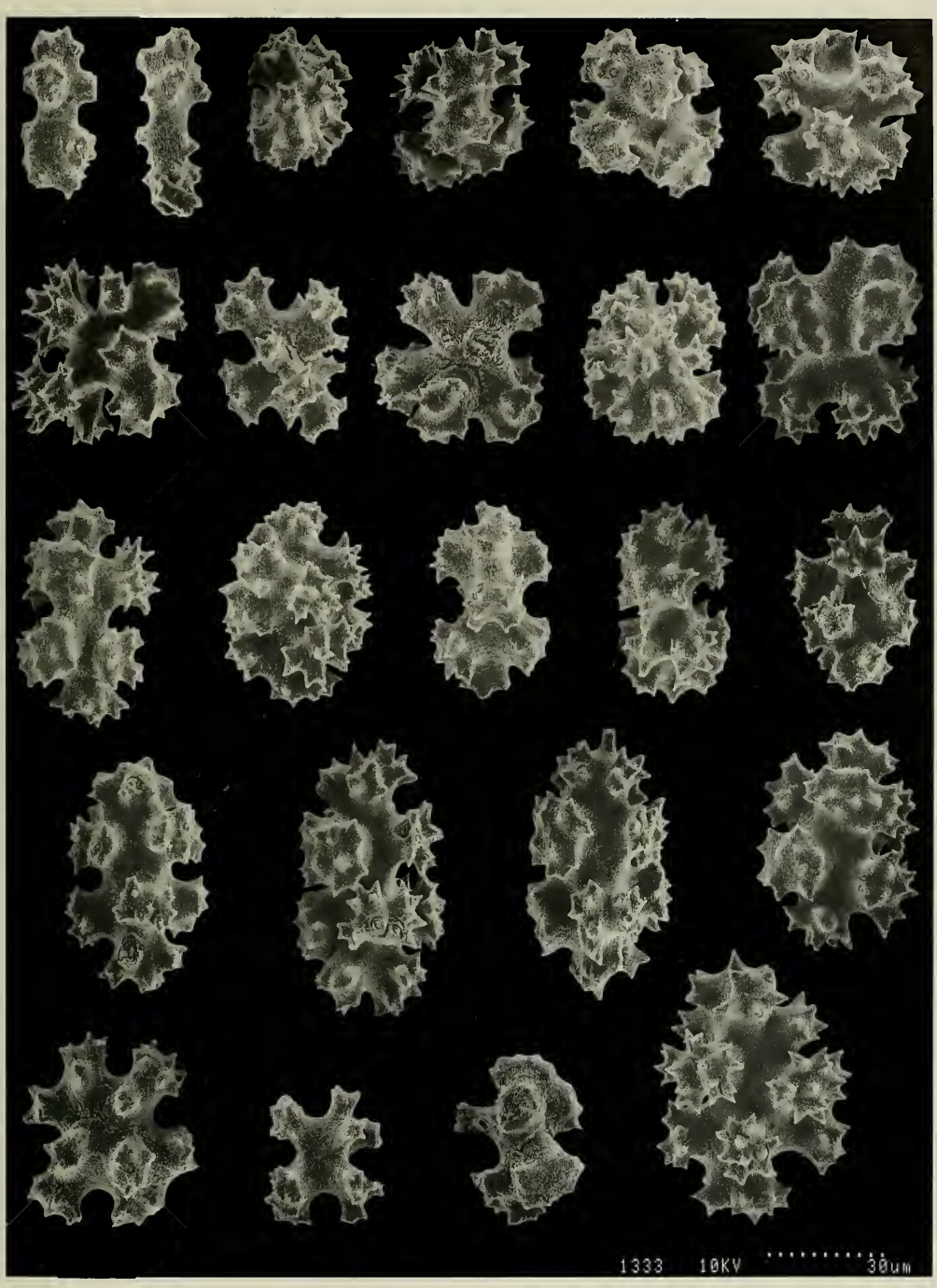

Fig. 10. *Corallium nix,* new species. Sclerites. SEM 1333.

vanishingly rare as to escape notice in preparations made both for SEM and light microscopy. The tentacles contain blunt rods derived from octoradiates, as shown by numerous intermediate forms.

Skeleton and coenenchyme white, sclerites colorless, translucent.

Etymology.—Latin *nix, nivis* f., snow, in allusion to the white corallum. Noun in apposition.

Comparisons.—The distinct axial pits with beaded margins in which the autozooids of *Corallium nix* are recessed are similar to those of *Corallium stylasteroides* Ridley, *C. salomonense* (Thomson & Mackinnon), and *C. thrinax* Bayer & Stefani. However, the sclerites of *C. stylasteroides* are smaller and not so sharply sculptured, and those of *C. salomonense* are both larger and more acutely sculptured. *C. thrinax* differs conspicuously in its small, dichotomously branched uniplanar growth form and its strongly asymmetrical double-club sclerites.

Corallium kishinouyei, new species
Figs. 11–19

Material examined.—Cross Seamount: 18°46.6′N, 158°14.8′W, 1145m. *Pisces V* dive PV235, coll. Scott France and Ewann Agenbroad, station CR105, 18 Aug 1993. Sample 1: One incomplete colony 11.5 cm tall with 2 detached branches, holotype USNM 94462 (SEM 2381, 2382, 2423). Sample 4: One incomplete colony consisting of one branch 12 cm tall and 4 smaller branches from the same colony, the largest 11 cm tall, USNM 94463, paratype (SEM 2285, 2455).

Diagnosis.—*Corallium* sparsely branched, roughly in one plane; autozooids biserial and weakly directed toward one face of the colony, a few on front of branches, not seated in distinct deep pits in the axis; axis longitudinally grooved. Predominant sclerites are short 8-radiate capstans and short, stubby 6- and 7-radiates not modified as double clubs; crosses extremely rare. Colonies white in ethanol, sclerites colorless.

Description.—Colonies sparingly branched in one plane, openly dichotomous or lateral (Fig. 11), the smaller terminal branchlets more or less clavate (Fig. 12). The stoutest main branch is nearly round, 7.2 mm in diameter; the terminal branchlets are about 4 mm in diameter, with a tendency to flattening in the plane of branching. Autozooids are situated biserially and directed slightly toward one face of the colony (the "front"), with occasional individuals also on the front face roughly between bilateral pairs, becoming more generally scattered on the stoutest branches. They retract to form low, moundlike verrucae about 3 mm in diameter and at most 1 mm in height, the orifices with marginal lobes not necessarily as many as 8 but depending upon the degree of contraction. Numerous small, bluntly conical papillae less than 0.5 mm in diameter, each with an apical pore, cover the surface of the coenenchyme around and between the autozooids, are interpreted as siphonozooids but not confirmed by histological examination.

The predominant coenenchymal sclerites (Fig. 13) are 8-radiate capstans from about 0.05 mm up to 0.13 mm in length; 6-radiates are present also, and 7-radiates are uncommon; crosses are present, as are a few irregular forms. The tentacles contain slender, bluntly pointed rods up to about 0.09 mm in length, derived from the predominant 8-radiate form.

The mature axis is longitudinally striated but there are no deep, smooth pits beneath the autozooids. Depressions in the axis accommodating the autozooids are confined to apical regions, where they are irregular and do not have smooth bottoms and prominent beaded margins (Figs. 18, 19 top). As usual, the surface is ornamented with small, thorny protuberances (Fig. 16, bottom) suggesting the sculpture of the sclerites, but these are not indicative of sclerites embedded in the axial calcite. Locally, some of the axial protuberances are very prominent

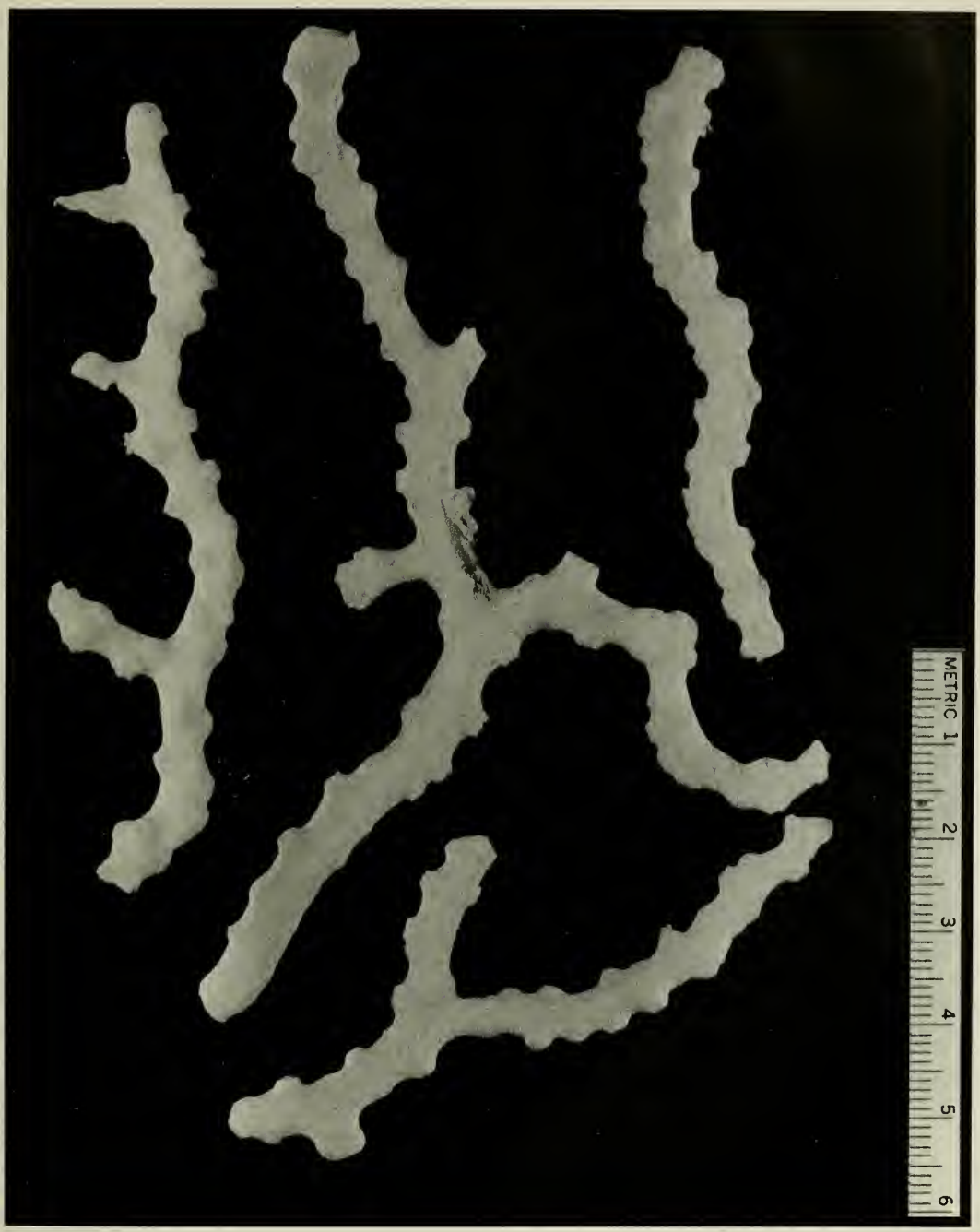

Fig. 11. *Corallium kishinouyei,* new species. Branches of holotype colony.

(Fig. 17, bottom) and resemble certain sclerites of other scleraxonians that do not occur in *Corallium* (e.g., the medullar sclerites of *Paragorgia*).

Owing to the limitations of the specimens available for study, only three apical samples from the axis from terminal twigs were prepared for examination by SEM,

Fig. 12. *Corallium kishinouyei,* new species. Tip of terminal twig with coenenchyme intact. SEM 2382, stereo pair.

one from USNM 94463 (Figs. 18, 19) and two from USNM 94462 (Figs. 14–16). Of the latter, the distal tip of the axis is in one case flattened and blade-like, the two flat faces each with two narrow ridges (Fig. 14, bottom) that probably accommodated the major longitudinal coenenchymal canals; in the other sample it is tapered, bluntly pointed, flattened but without the prominent longitudinal ridges (Fig. 15). The one axis tip examined from USNM 94463 is tapered, bluntly pointed, roughly prismatic, flattened on the "back" side, with irregular longitudinal ridges and intervening rows of irregular pits (Figs. 18, 19 top), the larger of which doubtless were situated beneath autozooids; the smaller pits are too small and too close together to underlie autozooids.

In all cases, the apex of the axis is composed largely of sclerites bound together by intervening non-spicular calcite (Figs. 16 top, 17 top, 19 bottom). This agrees with the conclusion of Grillo et al. (1993:127)

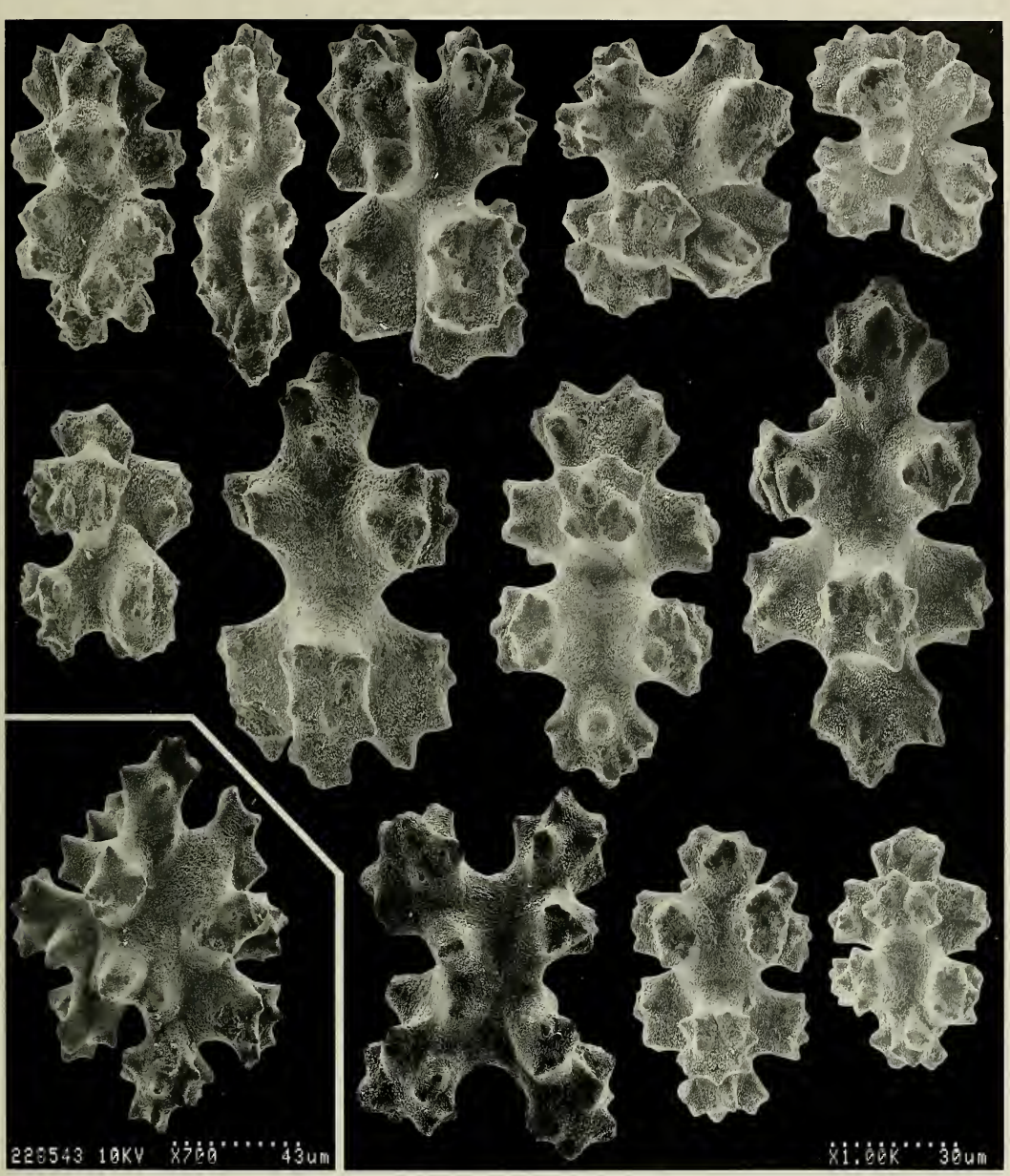

Fig. 13. *Corallium kishinouyei,* new species. Sclerites. SEM 2285.

that in *C. rubrum* "sclerites are incorporated to form the core of the nascent skeleton," subsequently becoming overlain by non-spicular calcite as the girth of the axis increases.

The color of the colonies in ethanol initially was distinctly yellowish white but the yellowish tint soon faded in alcohol; the sclerites are colorless. Those of the larger branches are predominantly opaque white, those of the terminal branches glass-clear, but there is no perceptible difference in

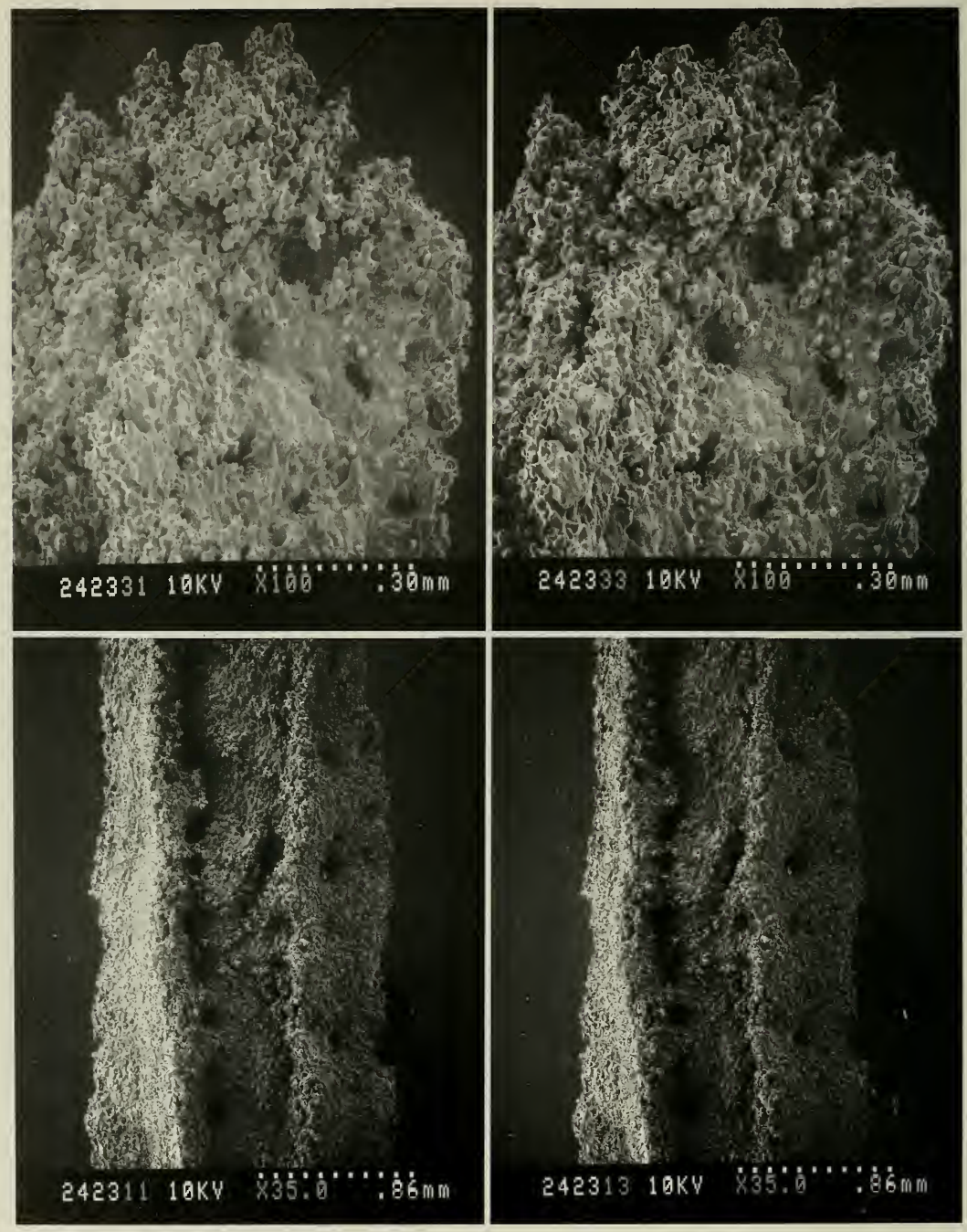

Fig. 14. *Corallium kishinouyei,* new species, axis of USNM 94462, preparation 1. Top, Apex; Bottom, Distal portion just below apex. SEM 2423, stereo pairs.

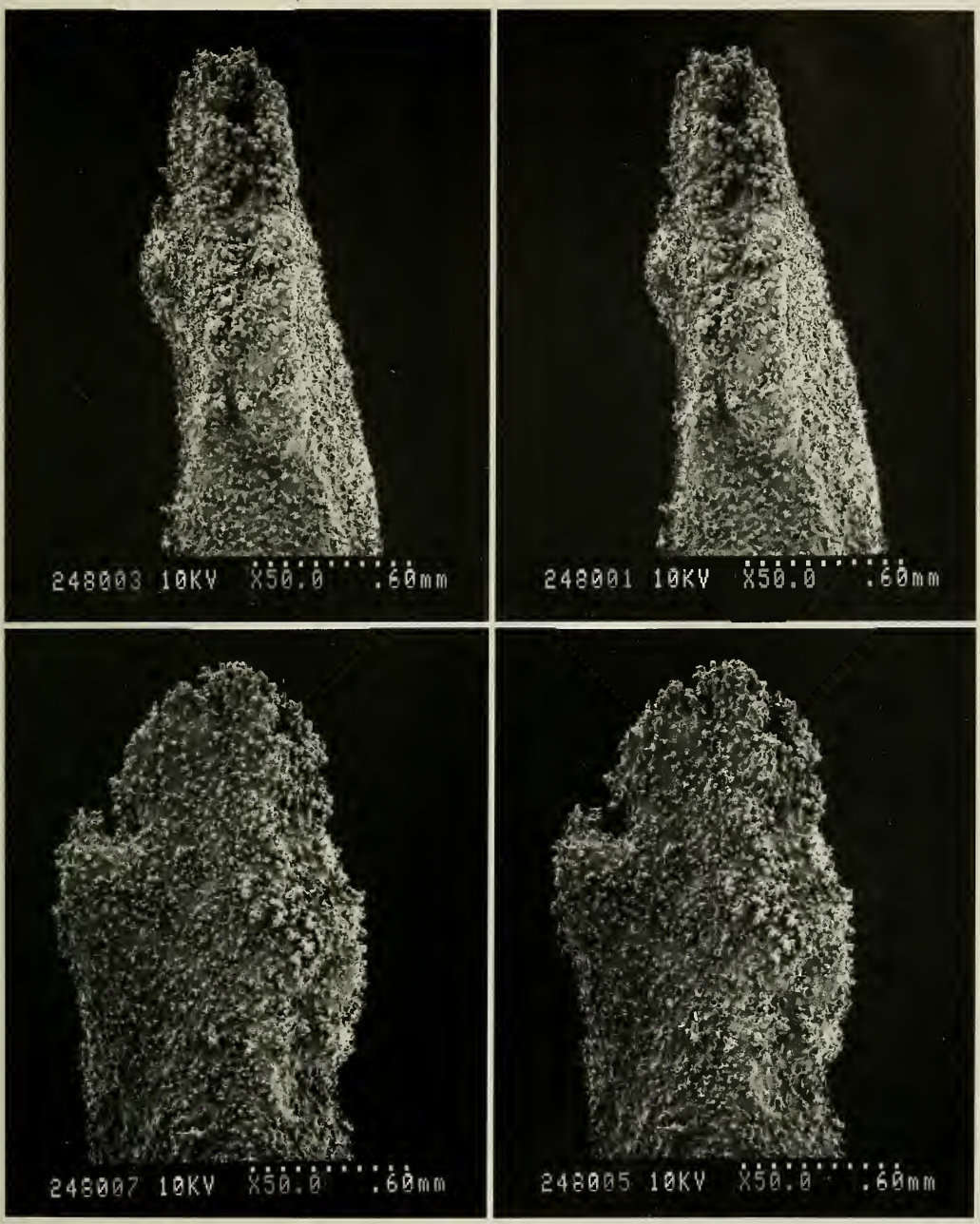

Fig. 15. *Corallium kishinouyei,* new species, axis of USNM 94462, preparation 2. Top, Apex from side; Bottom, Apex from front. SEM 2480, stereo pairs.

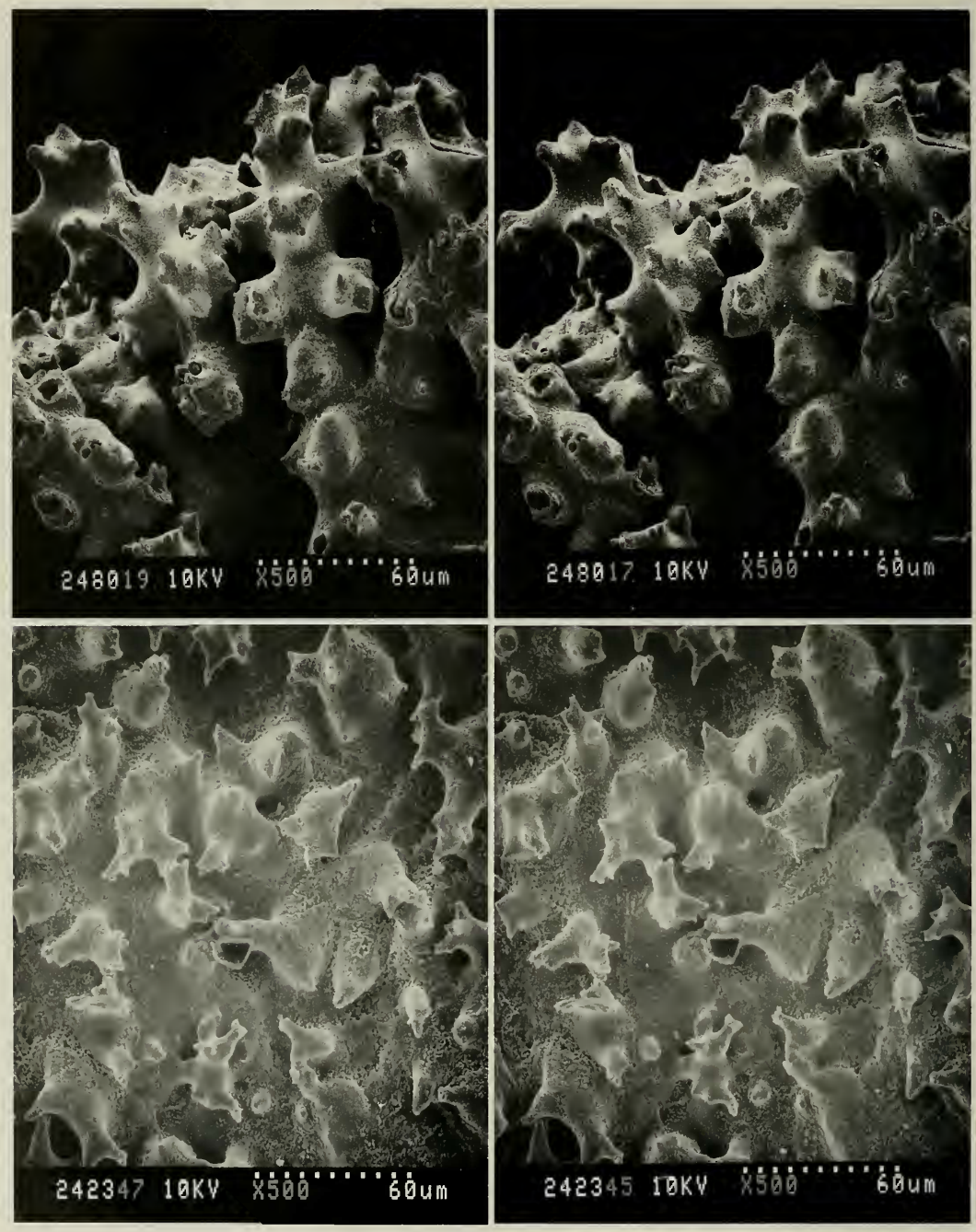

Fig. 16. *Corallium kishinouyei,* new species, axis of USNM 94462, preparation 1. Top, Sclerites embedded in non-spicular calcite at apex, SEM 2480; Bottom, Axial protuberances, SEM 2423. Stereo pairs.

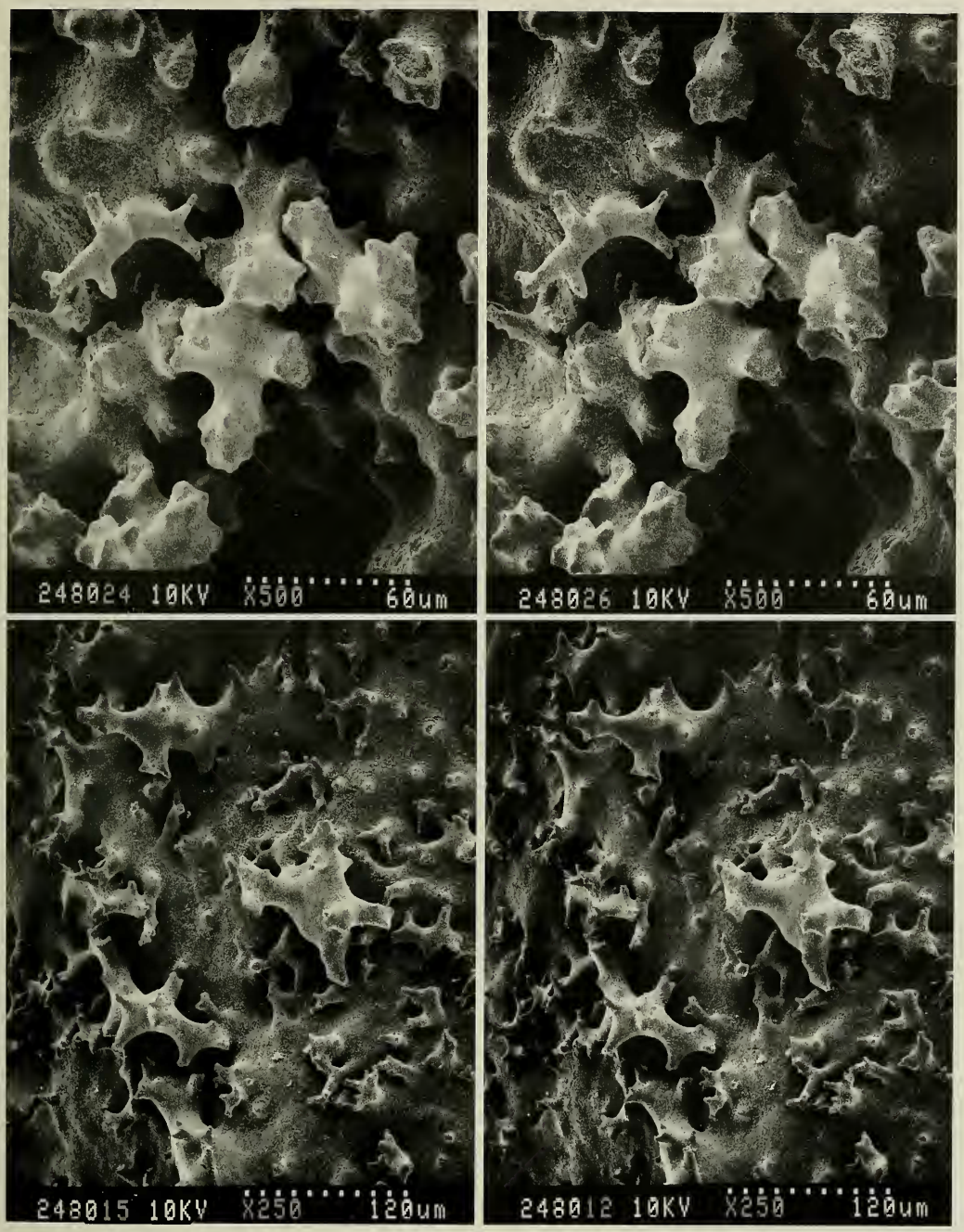

Fig. 17. *Corallium kishinouyei,* new species, axis of USNM 94462, preparation 1. Top, Surface of axis near apex, showing embedded sclerites and axial protuberance; Bottom, Surface of axis with typical axial protuberances and unusually large spiny projections. SEM 2480, stereo pairs.

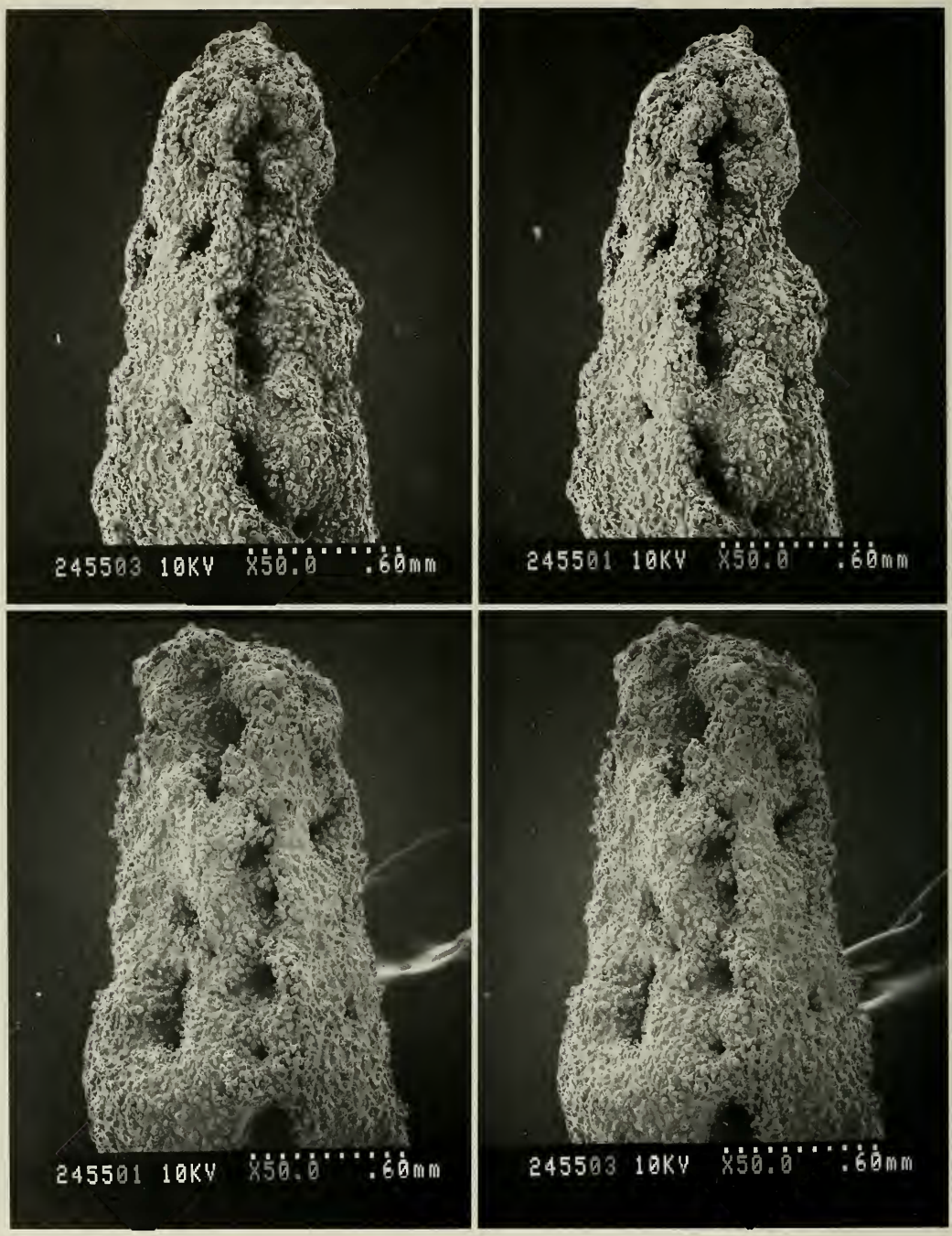

Fig. 18. *Corallium kishinouyei,* new species, axis of USNM 94463. Top, Apex of axis, side view; Bottom, Apex of axis, front view. SEM 2455, stereo pairs.

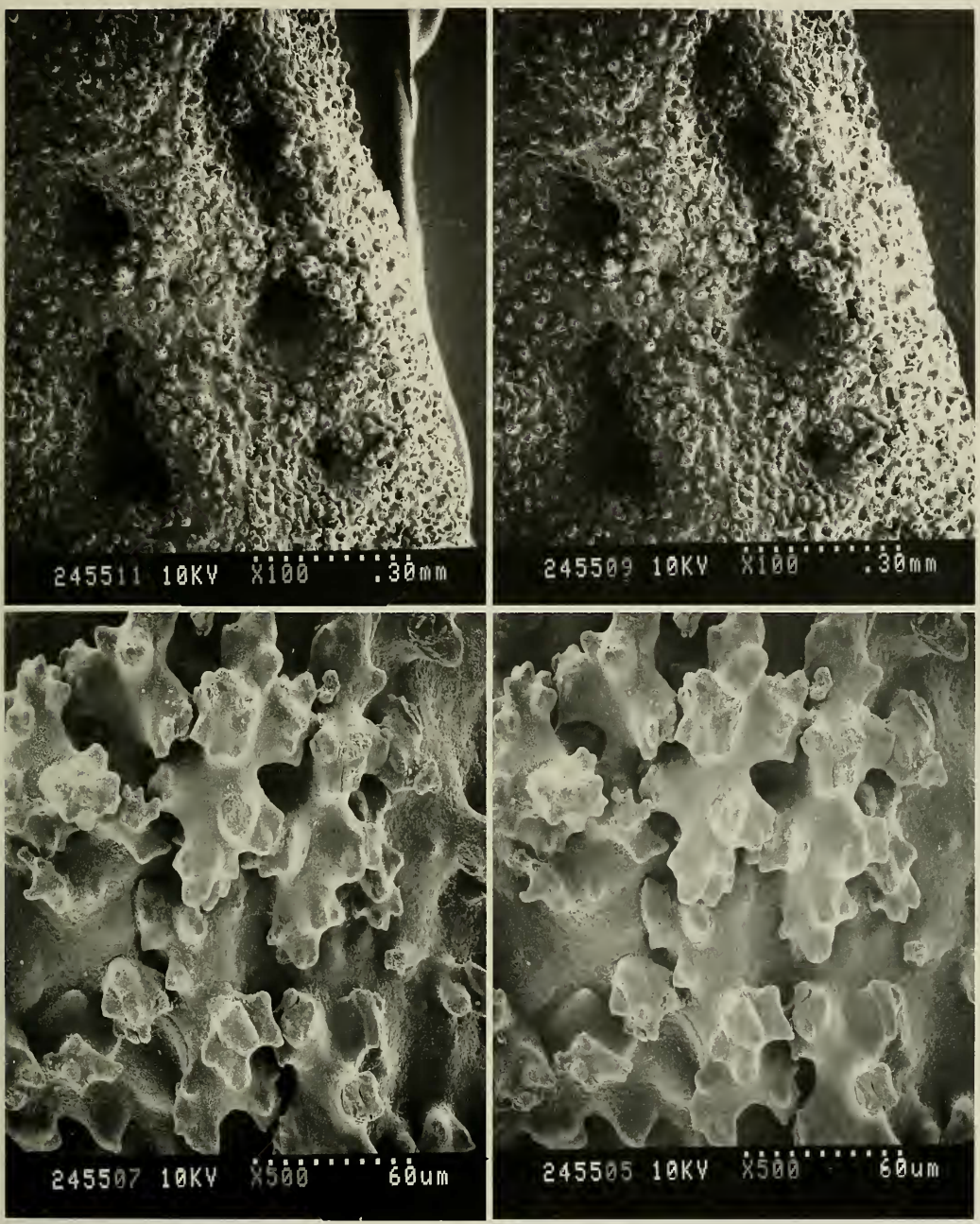

Fig. 19. *Corallium kishinouyei,* new species, axis of USNM 94463. Top, surface showing pits without beaded rim; Bottom, Surface near apex, showing embedded sclerites. SEM 2455, stereo pairs.

crystal structure that might account for this difference in opacity.

Etymology.—Named in honor of Kamakichi Kishinouye, pioneer Japanese investigator of precious corals.

Comparisons.—The openly branched, uniplanar colonial form of *Corallium kishinoueyi* is unlike any other species described so far, and the sclerites reach a larger size than in any species heretofore known.

Acknowledgments

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